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Indian Standard

RECOMMENDATIONS FOR DESIGN OF SCREW HOISTS FOR HYDRAULIC GATES

UDC 627·833 : 621·876

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4

March 1986

Indian Standard

RECOMMENDATIONS FOR DESIGN OF SCREW HOISTS FOR HYDRAULIC GATES

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Indian Standard

RECOMMENDATIONS FOR DESIGN OF SCREW HOISTS FOR HYDRAULIC GATES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 February 1985, after the draft finalized by the Hydraulic Gates and Valves Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Controlled release of water to canals is made by the use of gates provided on head regulators, cross regulators, control gates in conduits and tunnels or in the body of a dam. For the operation of such small size low head gates, generally the screw hoists are used.

0.3 A screw hoist is quite simple in construction and consists of a cast iron or fabricated pedestal resting on a platform. A screw stem passes through the pedestal and platform and is connected to the gate by means of nuts. The screw stem engages with a long threaded bronze nut which freely rotates in the pedestal, where thrust bearings are provided. As the nut rotates, the stem is lifted up or lowered down depending upon the direction of rotation of nut and the gate gets correspondingly lifted or lowered down. The source of power for the rotation of nut is a rotating crank (in case of hand operated screw hoists and electric motor in case of power driven screw hoists), set of spur gears, bevel pinion and bevel gear.

0.4 The screw hoist is used when a positive thrust is required to close the gate. The screw hoist is also used in case of low capacity manually operated hoist where it may not be necessary to provide any other electrically operated hoisting system. It is very compact and more economical as compared to other types of hoists. The use of screw hoist will be limited where gate vibrations are involved because of the fact that screw threads will get damaged under those conditions. The efficiency of the screw is also low. The screw hoist is used for gates with single or double point consideration.

0.5 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to the practices in the field in this country.

1. SCOPE

1.1 This standard lays down guiding principles for design of manually-operated and motor-operated screw hoists used for operation of hydraulic gates.

2. GENERAL

2.1 Typical general arrangement of screw hoist and the connection of items is shown in Fig. 1 to 3.

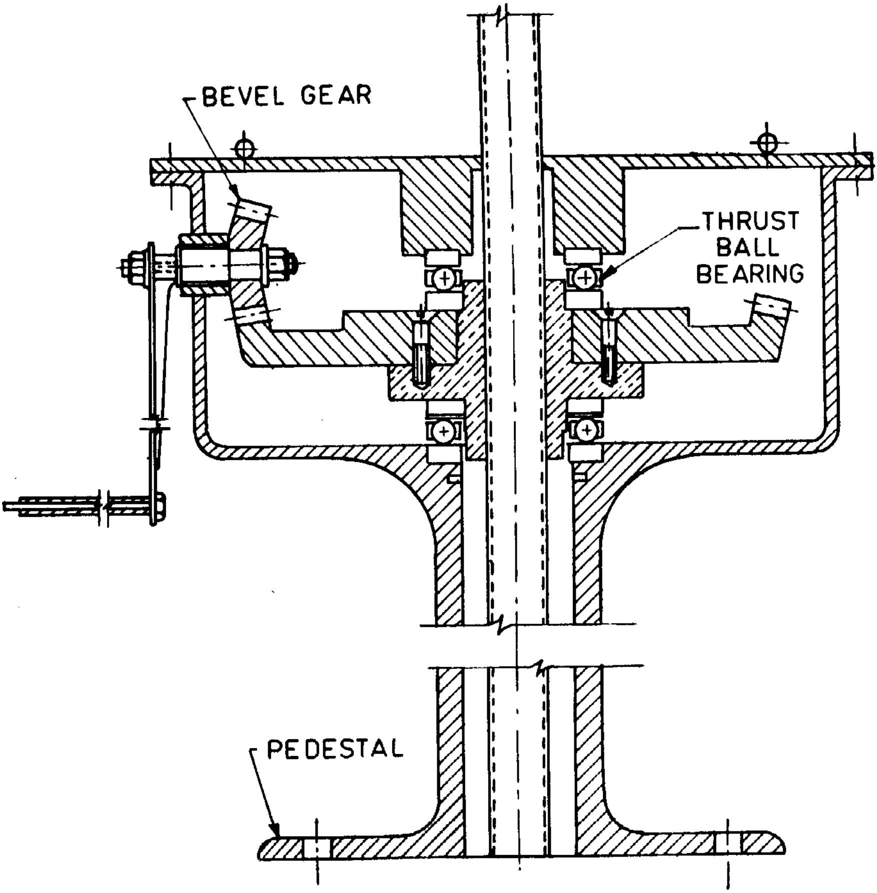

Fig. 1 Typical Arrangement for a Hand-Operated Screw Hoist

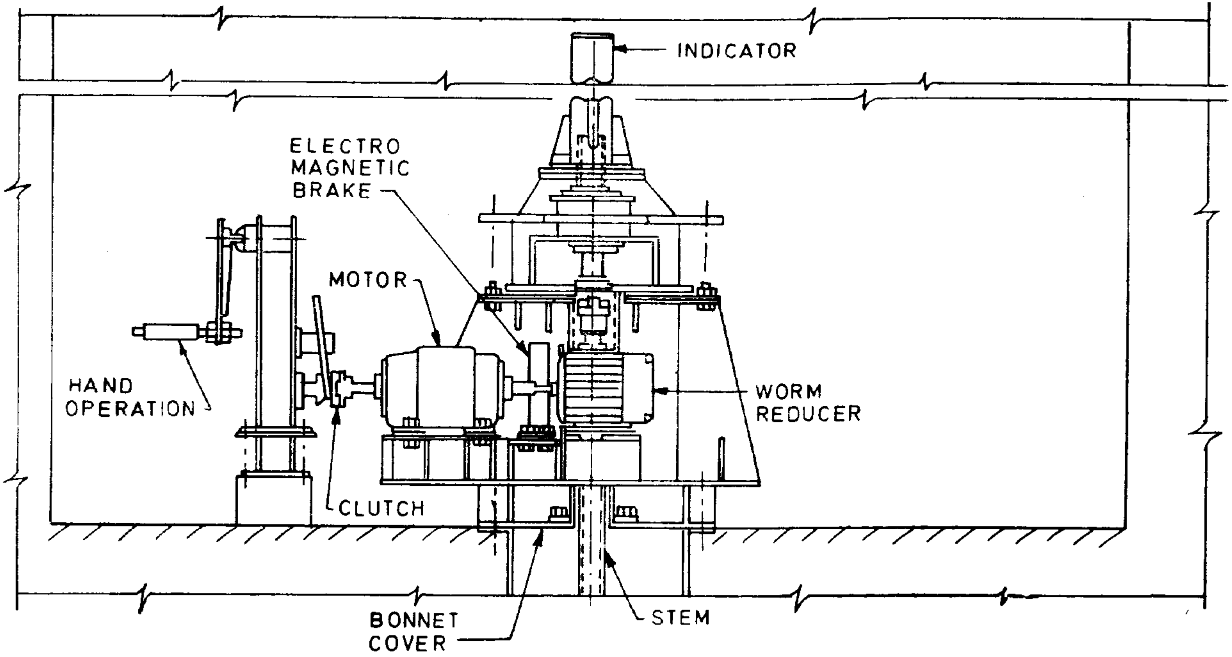

Fig. 2 Typical Arrangement of Motor Driven Screw Hoist

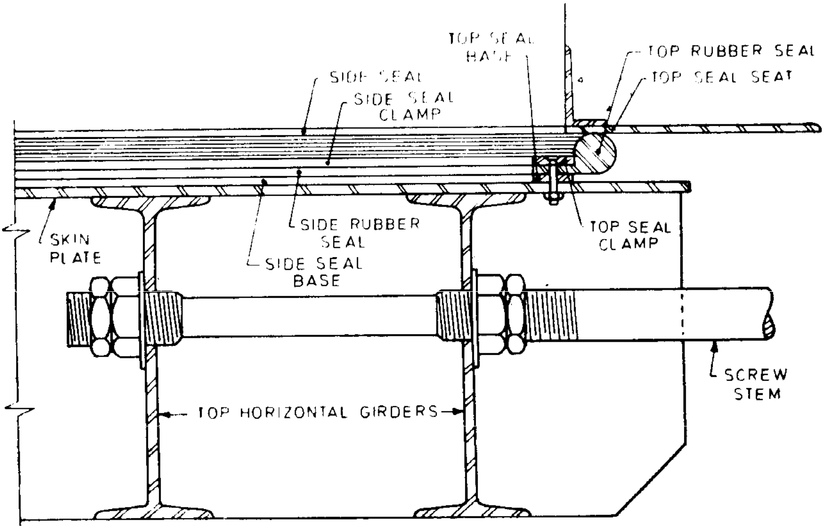

FIG. 3 TYPICAL CONNECTION OF STEM TO GATE

3. HOIST CAPACITY

3.1 The hoist capacity shall be determined by taking into consideration the following forces which might be required to be overcome:

a) Weight of the gate along with all its components including gate stem, intermediate stems, etc;

b) All frictional forces comprising;

  1) Wheel friction or slide friction,

  2) Guide friction, and

  3) Seal friction.

c) Any hydro-dynamic load, like down pull force/uplift, etc;

d) Silt and ice load wherever encountered;

e) Seating pressure as prescribed in **3.4**; and

f) Any other consideration specific to a particular site.

3.2 The worst combination of the above forces, during either lowering cycle or raising cycle, shall be considered.

3.3 The net hoist capacity will be obtained by increasing the hoist capacity thus arrived at by 20 precent to add for the reserve hoist capacity.

TABLE 1 MATERIAL AND DESIGN STRESSES FOR THE COMPONENTS OF SCREW HOIST

(*Clause* 4.1)

SL No.	COMPONENT/ PART	RECOMMENDED MATERIAL	REFERENCE	ALLOWABLE DESIGN STRUCTURES		
				Direct Bending	Shear	Bearing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Stem	Mild steel	IS : 226-1975* IS : 2062-1980†	0·4 YP	0·28 YP	0·75 YP
		Forged steel	IS : 1570-1961‡ IS : 1875-1978§			
		Corrosion resistant/ stainless steel	IS : 1570-1961‡			
ii)	Nut	Phosphor bronze	IS : 28-1975‖	—	0·03 UTS	0·04 UTS
iii)	Gear pinion	Forged steel	IS : 1875-1978§	0·4 YP	0·28 YP	0·75 YP
		Carbon steel	IS : 1570-1961‡			
		Cast steel	IS : 1030-1974¶			
iv)	Shafts, keys	Mild steel	IS : 226-1975* IS : 2062-1980†	0·4 YP	0·28 YP	0·75 YP
		Forged steel	IS : 1875-1978§ IS : 1570-1961‡			
v)	Gear box, hoist bridge	Structural steel	IS : 226-1975* IS : 2062-1980†	0·67 YP	0·47 YP	0·75 YP
vi)	Pedestal	Structural steel	IS : 226-1975* IS : 2062-1980†	0·67 YP	0·47 YP	0·75 YP
		Cast steel	IS : 1030-1974¶			
		Cast iron	IS : 210-1978**			
vii)	Bonnet and bonnet cover	Structural steel	IS : 226-1975*	0·67 YP	0·47 YP	0·75 YP

NOTE — Under breakdown conditions the allowable stress shall be 0·80 YP.

*Structural steel (standard quality) (*fifth revision*).
†Structural steel (fusion welding quality) (*second revision*).
‡Schedules for wrought steels for general engineering purposes.
§Carbon steel billets, blooms, slabs and bars for forgings (*fourth revision*).
‖Phosphor bronze ingots and castings (*third revision*).
¶Carbon steel castings for general engineering purposes (*second revision*).
**Grey iron castings (*third revision*).

3.4 The gate may be required to be given an additional downward thrust to make it seat properly on the silt to achieve the proper seal compression. While calculating the total hoist capacity during the closing cycle, the necessary closing/seating load required, when the gate is about to seat on the bottom seal, shall be greater than the value given below:

Type of Gate	*Minimum Seating Load*
Low head gates	2·5 kN/m
Medium head gates	5·0 kN/m
High head sluice gates	10·0 kN/m

3.5 The usual lifting speed of the motor-operated screw hoist shall be 20 to 70 cm per minute and for the manually-operated screw hoist shall be governed by provision contained in **5.10**. However, other values may be adopted depending upon the requirements.

4. MATERIAL AND DESIGN STRESSES

4.1 The recommended materials and design stresses for various components of screw hoist are given in Table 1. Where any material has not been specified, it shall be the best available for the purpose for which it is intended to be used and shall conform to the relevant Indian Standards.

5. DESIGN OF MECHANICAL COMPONENTS

5.1 General Requirements

5.1.1 The various components of hoist mechanism shall be so proportioned as to take the worst load coming on individual component.

5.1.2 The stress in various components of hoist shall be checked for maximum power transmission in these components, taking into account the permissible stresses as given in the relevant clauses.

5.1.3 All the hoisting machinery parts shall be checked for static as well as dynamic loads.

5.1.4 The combined stresses in various components shall be found by the following formulae :

a) $\sigma_c = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 + 3\tau^2}$

b) $\sigma_s = \frac{1}{2} \sqrt{\sigma_1^2 + 4\tau^2}$

c) $\sigma_t = \frac{1}{2} (\sigma_1 + 2\sigma_s)$

where

σ_c = maximum combined stress in N/m^2,

σ_s, σ_t = Maximum combined shear and tensile stresses in N/m^2,

σ_1, σ_2 = Tensile/compressive stresses in N/m^2, and

τ = Shear stresses in N/m^2.

5.2 Stem

5.2.1 *General* — The stem shall normally be made of mild steel or forged steel or corrosion resistant steel. It may be of galvanized or nickel chrome plated in the unthreaded portion, If so required.

5.2.2 The stem shall be provided with standard metric thread conforming to IS : 4218-1976* at one end for connection with the gate. It shall normally be connected to the horizontal girders and shall be required to be tightened against a minimum of two girders as per the arrangement shown in Fig. 3. The bottom end shall be provided with an additional lock nut. In case the gate does not require positive thrust for closing, pin jointing the stem to the gate may be considered.

5.2.3 Standard square threads conforming to IS : 4694-1968† or acme threads shall be cut on the stem at the other end for transmission of power. The minimum length for which the threads may be provided shall be the sum of the following:

a) Total lift of the gate,
b) Length of the nut in contact with the stem, and
c) Extra allowance of 300 mm.

More than one start of the screw threads shall be provided in order to achieve quick linear movement.

5.2.4 The screw stem rod shall be designed for direct torsional compressive load by taking the root diameter at the minimum cross-section. The diameter so arrived at shall be checked for torsional shear stress, buckling and for combined maximum shear and maximum tensile compressive stresses. Suitable supports may be provided at intermediate points, if required.

5.2.5 For calculating the torque transmitted by the screw threads the following formula may be used.

$$T = P.\frac{d}{2}\left[\frac{\pi\,\mu\,d\sec\beta + L}{\pi\,d - \mu\,L\sec\beta}\right]$$

---

*ISO metric screw threads.

†Basic dimensions for square threads.

where

T = torque transmitted,
P = hoist capacity,
d = pitch circle diameter of threads,
μ = co-efficient of friction,
L = lead of the screw threads, and
β = half the included angle of the threads. In the case of parallel sides of square threads, the term ' Sec β ' may be omitted from the formula.

5.3 Nut

5.3.1 *General* — The nut, through which the power is to be transmitted to the stem, shall generally be of a material having lesser wear resistance then the material of the stem.

5.3.2 Square or acme threads matching with those provided on the screw stem shall be provided on the inner surface of the nut. The total number of threads to be cut on the nut shall be calculated on the basis of the total bearing area to be provided. The bearing pressure on the threads of phosphor bronze nut shall not exceed 0·04 UTS. The total length of the nut shall also be governed accordingly.

5.3.3 The number of threads provided on the basis of the bearing stress shall be checked for shear stress at the threads cross section. The minimum outside diameter of the nut shall be at least twice the minimum inside diameter.

5.3.4 *Efficiency of Transmission* — The efficiency of the power transmission between the nut and stem shall depend on the type of threads used. The following formulae may be used for calculating the transmission efficiency:

$$\eta = \frac{\tan\alpha\,(1 - \mu\tan\alpha)}{\tan\alpha + \mu} \quad \text{for square threads}$$

$$\eta = \frac{\tan\alpha\,(1 - \mu\sec\beta\tan\alpha)}{\tan\alpha + \mu\sec\beta} \quad \text{for acme threads}$$

where

η = efficiency,
α = helix angle of the screw threads,
β = half the included angle for acme threads, and
μ = co-efficienty of friction.

5.4 Gearing

5.4.1 *General* — Any of the following gear systems or a suitable combination of these may be used in the screw hoist:

a) Spur gears,
b) Bevel gears, and
c) Worm and worm wheel

5.4.2 *Design of Spur Gears* — Unless more accurate methods are applied and called for, the spur gears shall be designed according to the formula given below :

$$\sigma \text{ root} = \frac{p \times q}{f \times m}$$

where

σ root = stress in N/mm^2 at root of gear,
p = tooth pressure or load in N,
q = strength factor indicated in Table 2,
f = face width in m, and
m = module in m.

TABLE 2 VALUE FOR CALCULATION OF STRESS IN TOOTH AT ROOT (EXTERNAL TOOTH) FOR 20° AND 14½° FULL DEPTH INVOLUTE SYSTEM

NUMBER OF TEETH ON GEAR/PINION	q VALUE	
	For 20°	For 14½°
(1)	(2)	(3)
12	4·6	—
13	4·35	5·38
14	4·10	5·22
15	3·90	5·07
16	3·75	4·93
17	3·60	4·80
18	3·50	4·68
21	3·3	4·37
24	3·2	4·13
28	3·1	3·90
34	3·0	3·70
40	2·9	3·50
50	2·8	3·40
65	2·7	3·27
80	2·6	3·18
100	2·5	3·10
Above 100	2·5	2·20

NOTE—Intermediate values may be interpolated.

5.4.3 *Design of Bevel Gears*

5.4.3.1 For design of the bevel gears two additional weighing factors will be used in the above formula. These are the bevel factor and the velocity factor. These are defined below:

5.4.3.2 The bevel factor shall be calculated by the formula :

$$\delta = \frac{C_d}{C_d - f}$$

where

δ = bevel factor,

C_d = cone distance of the bevel gears, and

f = face width.

5.4.3.3 The velocity factor shall be calculated by the following formula:

$$\omega = \frac{185}{185 + V_p}$$

where

ω = velocity factor, and

V_p = peripheral velocity in m/s at the pitch circle diameter.

5.4.3.4 The formula in **5.4.2** for calculating root stress of the gear shall, therefore, be modified as :

$$\sigma \text{ root} = \frac{p \times q}{f \times m} \times \frac{\delta}{\omega}$$

5.4.4 Standard worm or helical reducer, if used, for the first stage reduction at the drive unit, shall be of high grade suitable for the service intended. Rating and efficiency of the reducer used in calculation shall be as per manufacturer's recommendations.

5.5 Shafts, Key and Keyways

5.5.1 *General* — The shafts shall be designed for appropriate load/torque that is being transmitted. Shafts shall have ample strength and rigidity and adequate bearing surfaces. They shall be finished smoothly and provided with suitable changes of cross-section for easy assembly and disassembly.

5.5.2 *Dimensioning of Shafts* — In dimensioning the shafts with ratio of length/diameter greater than 50, the angle of twist and the revolutions/minute shall be taken into account, in addition to simple bending, pure torsion, or the combined effect of bending and torsion. The twist that shall be permitted is $\frac{1}{4}^\circ$ to $\frac{1}{3}^\circ$ per metre. Linear deflection in the shaft shall not exceed 1·0 mm/m length.

5.5.3 All keys and keyways shall be designed in accordance with IS : 2048-1975*. Keyways shall not be extended into the bearings.

5.6 Bearings

5.6.1 *General* — All the running shafts shall be provided with ball, roller or bush bearings. Selection of bearings shall be done on consideration of duty, load and speed of the shaft. Life of ball and roller bearings shall be calculated in accordance with the manufacturer's recommendations. All bearings shall be easily accessible for lubrication and/or replacement.

5.6.2 *Thrust Bearings* — The special thrust bearings required for taking the entire hoisting/lowering load shall be provided between the nut and the pedestal body.

5.7 Couplings

5.7.1 All couplings shall be of forged steel, cast steel or cast iron and shall be designed to transmit the maximum torque that may be developed (*see* IS : 2693-1980† and IS : 3653-1966‡).

5.7.2 Solid couplings shall be aligned in such a way that they meet accurately. Flexible couplings shall be initially aligned with the same accuracy as solid couplings.

5.8 Gear Boxes

5.8.1 Gear boxes shall be of rigid construction fitted with inspection covers and lifting handles, where necessary. The gear boxes shall be so designed that the gears may be easily removed or replaced, and shall be such that the gears remain suitably lubricated. In case of oil lubrication, facilities for oil filling and draining, connection for oil level indicator and adequate breathing arrangement shall be provided, wherever necessary. The gear boxes shall be mounted on a level surface.

5.8.2 The gear box shall be made of cast iron or cast steel or fabricated from mild steel.

5.9 Pedestal

5.9.1 The pedestal shall be fabricated or cast and shall be mounted on hoisting platform. The pedestal shall be designed as a column against crippling due to total hoist and shall preferably have tapered sides in order to achieve greater stability. The centre line of the operating handle shall be maintained at a height of 900 to 1 000 mm from the floor.

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*Parallel keys and keyways (*first revision*).

†Bush type flexible couplings for power transmission (*first revision*).

‡Dimensions for forged end type rigid couplings.

5.10 Manual Operation

5.10.1 The manual operation arrangement shall be so designed that the continuous effect per man does not exceed a crank force of 100 N at 400 mm crank radius at a continuous rating of 24 revolutions per minute.

5.10.2 Hoists of capacity up to 7·5 tonnes may normally be provided with only manual operation arrangement unless otherwise agreed upon between the supplier and the purchaser. However, hoists of larger capacities provided with electrical operation shall also be provided with an emergency hand operation arrangement.

5.10.3 In case of electrically operated hoists, suitable electrical interlocks shall be provided to prevent operation by electrical power when the manual drive is engaged.

5.11 Bonnet and Bonnet Cover

5.11.1 The bonnet, housing the gate in open position shall be either of cast steel or of structural steel in welded construction. It shall be adequately ribbed to provide proper anchorage with surrounding concrete and the ribs, so provided shall have enough openings to allow for proper concreting behind the groove liners. The bonnet shall be designed to enable the gate guides to run continuously.

5.11.2 The bonnet cover shall be designed for full hydrostatic pressure and also for the hoist capacity if the hoist is directly mounted over it. It shall be either in one piece/or more according to requirements. Provision for venting of air shall be made in the bonnet cover.

5.12 Gate Position Indicator

5.12.1 A separate indicator of the circular dial type or vertical scale type shall invariably be provided for each gate to show the gate position at any time. The dial or scale shall be made of a non-rusting metal or of enamelled plate or thick plastic sheet. Permanent, prominently visible markings shall be made on the dial to read every 1/10 of a metre. The gate position of ‘closed’, ‘open’ and ‘fully raised’ shall also be marked on the dial. The indicator point shall be made of non-rusting metal.

5.13 The design of all the mechanical components shall be checked for breakdown torque condition. The stresses developed in the mechanical components under breakdown torque condition shall not exceed 30 percent of the yield point for that material.

6. ELECTRICAL EQUIPMENT

6.1 General — All electrical equipments shall be suitably protected from moisture, condensation, corrossion, etc, by providing weatherproof covers and electrical heaters, wherever necessary. All equipments shall be of the best quality conforming to relevant Indian Standards.

6.2 Efficiency of System

6.2.1 The usual values of efficiencies adopted for the various elements of hoisting mechanism are given in Table 3. The overall efficiency of the system, which is the product of individual efficiencies of elements, shall then be worked out. This overall efficiency of the system shall be used in calculating capacity of the electric motor.

TABLE 3 EFFICIENCIES OF VARIOUS COMPONENTS OF HOISTING MECHANISM

SL No. (1)	PARTICULARS OF ELEMENTS (2)	STARTING EFFICIENCY (3)	RUNNING EFFICIENCY (4)
i)	Each set of spur gears	93 percent	95 percent
ii)	Each set of helical gears	95 percent	98 percent
iii)	Each set of bevel gears	91 percent	93 percent
iv)	Standard drive such as worm, reducers, helical gears reducers, etc	As per manufacturer's recommendations	
v)	Electrical motors	do	
vi)	Power screws	As calculated in **5.3.4**	

6.3 Provision of all electrical equipments such as, motors, electro-magneto brakes, limit switches and control equipment, such as control panels, indicator lamps, relays, switches, starters, and wiring shall be provided in accordance with IS : 6938-1973*.

6.4 Remote control equipment, if required, shall be provided to enable the operation of gates from some remote control room. Gate position indicators, suitably interlinked with local control panel, may also be provided in the remote control room.

6.5 Alternative source of electrical supply may be provided for important projects, if considered necessary.

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* Code of practice for design of rope drum and chain hoist for hydraulic gates.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	cr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2